aemerge®

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Request for Applicability Determination for Aemerge RedPak Services Southern California, LLC, Under Section 129 of the Clean Air Act

Dear Mr. Salazar:

This letter requests that the United States Environmental Protection Agency (EPA) determine the applicability of rules promulgated under Section 129 of the Clean Air Act (CAA) to the carbonizer/gasifier (carbonizer) system that Aemerge RedPak Services Southern California, LLC (Aemerge) has proposed for construction in Hesperia, California. Aemerge contends that the carbonizer is not a combustion unit or an incineration unit and is not, therefore, subject to the requirements of the incineration regulations promulgated under the requirements of Section 129 of the CAA. Furthermore, the carbonizer is a pyrolysis unit and as a pyrolysis unit, it is exempt from the requirements of 40 CFR 60 Subpart Ec, Standards of Performance for Hospital/Medical/Infectious Waste Incinerators (HMIWI).

The standard that EPA has employed in determining applicability of Section 129 requirements has been a determination of whether the specific unit under review supports combustion. EPA has defined combustion as:

> "Combustion is an exothermic chemical reaction involving the rapid thermal oxidation of a substance."[i]

The intent of this letter is to establish that the Aemerge carbonizer system is a pyrolysis system that is designed to prevent combustion through operation in an endothermic process conducted under a nitrogen blanket and negative pressure. The Aemerge process is inert gas carbonization that is a commercially available technology that is used for making carbon fiber and other carbon co-productions where oxidation of the carbon is undesirable. The waste processed in the Aemerge unit is contained in a sealed chamber (muffle) that receives indirect heat from an outer jacket that can be heated with natural gas or electric heat. The outer jacket is completely isolated from the inner muffle.

The intent of the design is to produce a high quality carbon with minimal ash and usable synthetic gas (syngas) that is utilized for energy recovery. Both the carbon and the syngas provide for beneficial use of the anaerobic thermal conversion derived materials. Organic ash is an oxidation product and is undesirable in carbonization. The nitrogen blanket and the negative pressure in the muffle combine with high pyrolytic heat from the surrounding furnace to drive off volatiles and provide a reducing environment that produces carbon used to make a variety of carbon co-products, including carbon fibers from the carbonaceous wastes provided as feed to the carbonizer.

Aemerge contends that the carbonizer technology is exemplary in meeting EPA's criteria for evaluating whether a unit is endothermic, can or cannot support combustion and is a pyrolysis unit. Combustion or oxidization is detrimental to the carbonization process. The nitrogen blanket and negative pressure in the unit are designed to eliminate combustion. The system monitors and shuts down with the presence of oxygen in the unit as this creates a safety hazard for operation. Gasification and carbonization are stages in the pyrolysis of carbonaceous material. Carbonization is the endpoint of pyrolysis where as a result of high temperature and a reducing (oxygen deprived) environment, carbonaceous material is reduced to elemental carbon. As carbonization is the endpoint of pyrolysis, it requires the highest input of outside energy and is therefore, the most endothermic form of pyrolysis. The specific design components of the Aemerge technology and their relationship to EPA regulatory applicability are discussed in detail below.

Background

The technical discussion of the specific attributes of the Aemerge system and how it relates to EPA evaluation criteria are discussed below. The first section presents the terms and definitions that will be applied to the applicability evaluation. The second section looks at prior EPA determinations and evaluates how these prior determinations relate to the specific merits of the Aemerge process.

Definitions and Terms

The Aemerge process utilizes a carbonization furnace; carbonization is the culmination of pyrolysis where carbonaceous material is converted to elemental carbon by reduction (the opposite of oxidation). Carbonization is a commercially available technology and inert gas carbonization muffle furnaces are commercially available and used in production of material such as carbon fiber. Carbonization is optimized by prevention of combustion (oxidation) as oxidization reduces carbon yield by creating carbon monoxide and carbon dioxide and +-producing ash (oxidation residues) that are impurities in the carbon produced.

Section 129 of the CAA authorizes EPA to regulate "Solid Waste Combustion". EPA has promulgated regulations under this authority to regulate "combustion units" for different categories of waste incinerators. This makes the definition of combustion under these rules significant and, consistent with this mandate, EPA has exempted from regulation under Section 129 those process units that have been determined not be "combustion units" or units where combustion is occurring. EPA has consistently held in the determination that will be presented below that units that do not combust solid waste cannot be subject to the requirements of Section 129.

The definition of combustion provided above from the Cotsworth memo is concise and consistent with other EPA statements, it states:

> "Combustion is an exothermic chemical reaction involving the rapid thermal oxidation of a substance."

An exothermic reaction produces heat and an endothermic reaction requires heat to take place. Oxidation is an exothermic process. Organic carbonaceous material is oxidized to carbon dioxide and water through oxidation. These combustion reactions produce substantial amounts of heat. Carbonization is essentially the opposite process. Oxygen, hydrogen and other molecules are stripped off the carbon molecules by inputting energy to produce elemental carbon. Carbonization, particularly in the absence of oxygen as conducted in the Aemerge process is, therefore, endothermic as both the carbon and the syngas produced by gasification result from the adsorption of heat from the furnace that surrounds the nitrogen blanketed muffle.

> "*Pyrolysis* means the endothermic gasification of hospital waste and/or medical/infectious waste using external energy. 40 CFR 60.51c - Definitions."
>
> "Definition of endothermic: characterized by or formed with absorption of heat", Merriam Webster dictionary
>
> "Definition of carbonize: to convert into carbon or a carbonic residue Merriam Webster dictionary

Carbonization is an established production process. The Aemerge process produces syngas through rectification, torrefaction and devolatilization. In carbonization, the final volatiles are removed leaving elemental carbon. This process is outlined in Figures A1 and A2 below and show that these are steps in pyrolysis as time and temperature are increased. This can be done exothermically with a high loss of carbon and high ash content and is the process used to make charcoal. When this is done with an inert gas added to expel oxygen and prohibit combustion, this process is called inert gas carbonization. This is the technology used by Aemerge and is a commercially available technology that is used in, among other processes, the production of carbon fibers. A carbon fiber inert gas carbonizer is depicted in Figure A3 below. This carbonizer shares the same essential elements as the Aemerge process in that it has indirect heat, a completely isolated muffle that does not contact the heater and nitrogen for the inert gas in the muffle.

Figure A1 – Pyrolysis involves multiple steps ending in carbonization for biomass

Pyrolysis of Biomass

- Thermal decomposition occurring in the absence of oxygen
- Above 300°C polymeric building blocks undergo crosslinking, depolymerization and fragmentation
- Smaller molecules are released as gases and vapors
  - can react with residual solids producing more condensed structures (Pyrosynthesis)
- "Always" produces solid (charcoal), liquid (water and organics), and gaseous (CO, CO_2, CH_4, H_2)
  - Proportions and composition dependent on feedstock and process conditions.

Figure A2 – The progressive steps of pyrolysis of biomass resulting in carbonization

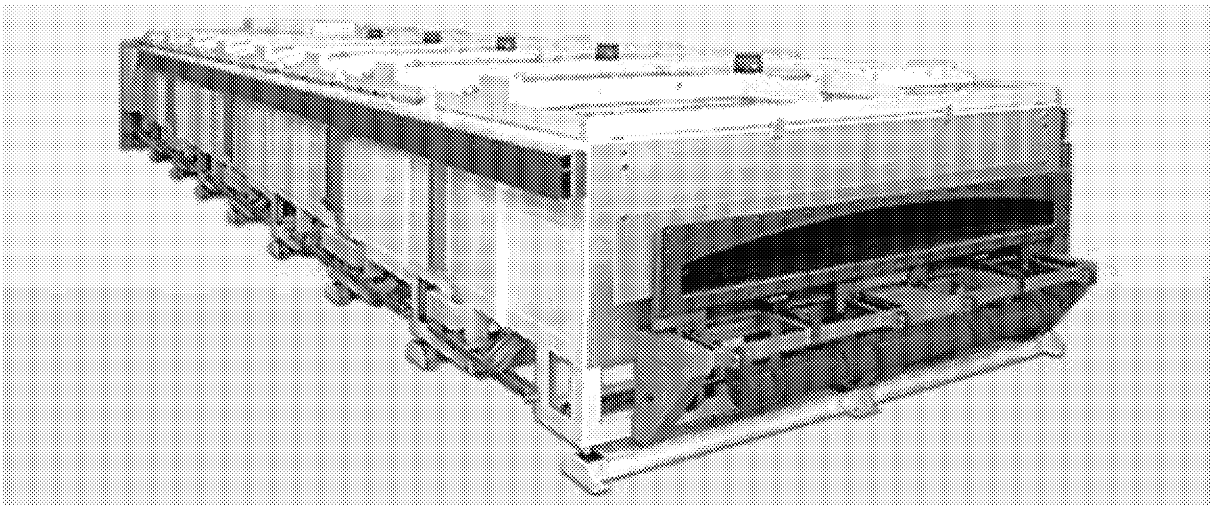
Slow Heating of Biomass

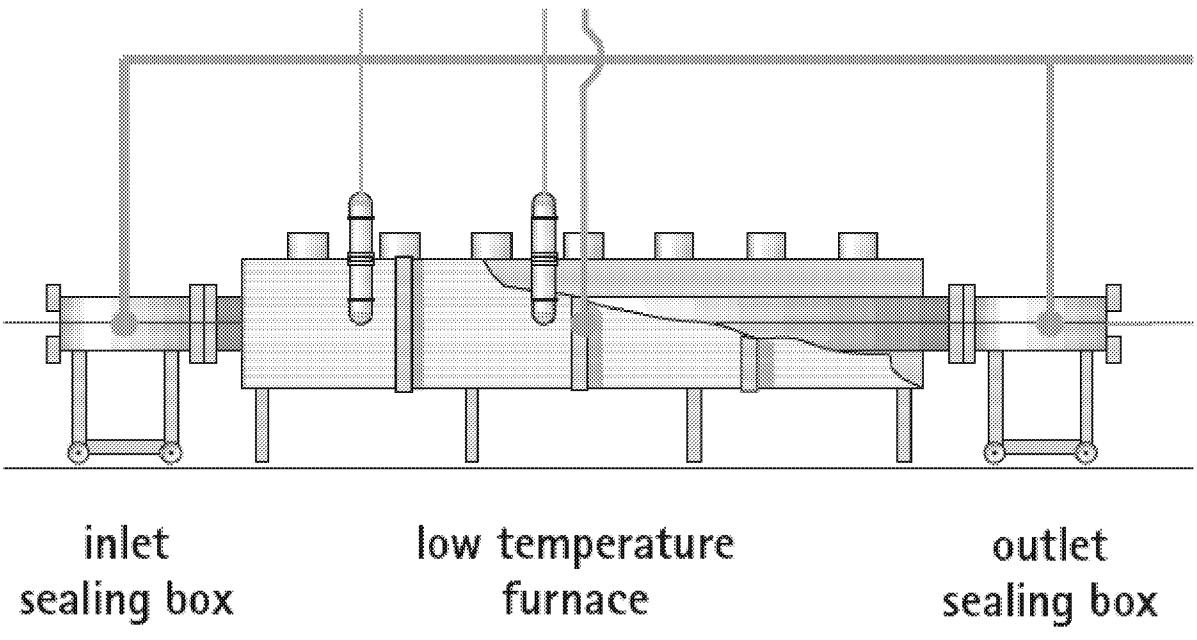
Temperature	*Solid Phase*	*Gas Phase*
<200°C	*Drying*	*H_2O*
230°C-250°C	*Retification*	*Acetic acid, MeOH*
250°C-280°C	*Torrefaction*	*Labile Deoxygenation*
300°C-500°C	*Devolatilization*	*Organics, H_2O, gas*
>500°C	*Carbonization*	*Aromatics, HC's, H_2O, gas*

The Relation of Pyrolysis Processes Properties, Robert J. Evans, DOE, National Renewable Energy Laboratory, Symposium on Black Carbon in Soils & Sediments; Formation, Stabilization, Abundance and Environmental Function, Joint meeting of The Geological Society of America, Houston TX
[HYPERLINK "http://www.biochar-international.org/images/Evans_SSSACharcoal100508-3.pdf"]

Figure A3 - Ruhstrat Muffle Pull-Through Furnace

FOR CARBONIZING SYNTHETIC FIBRE





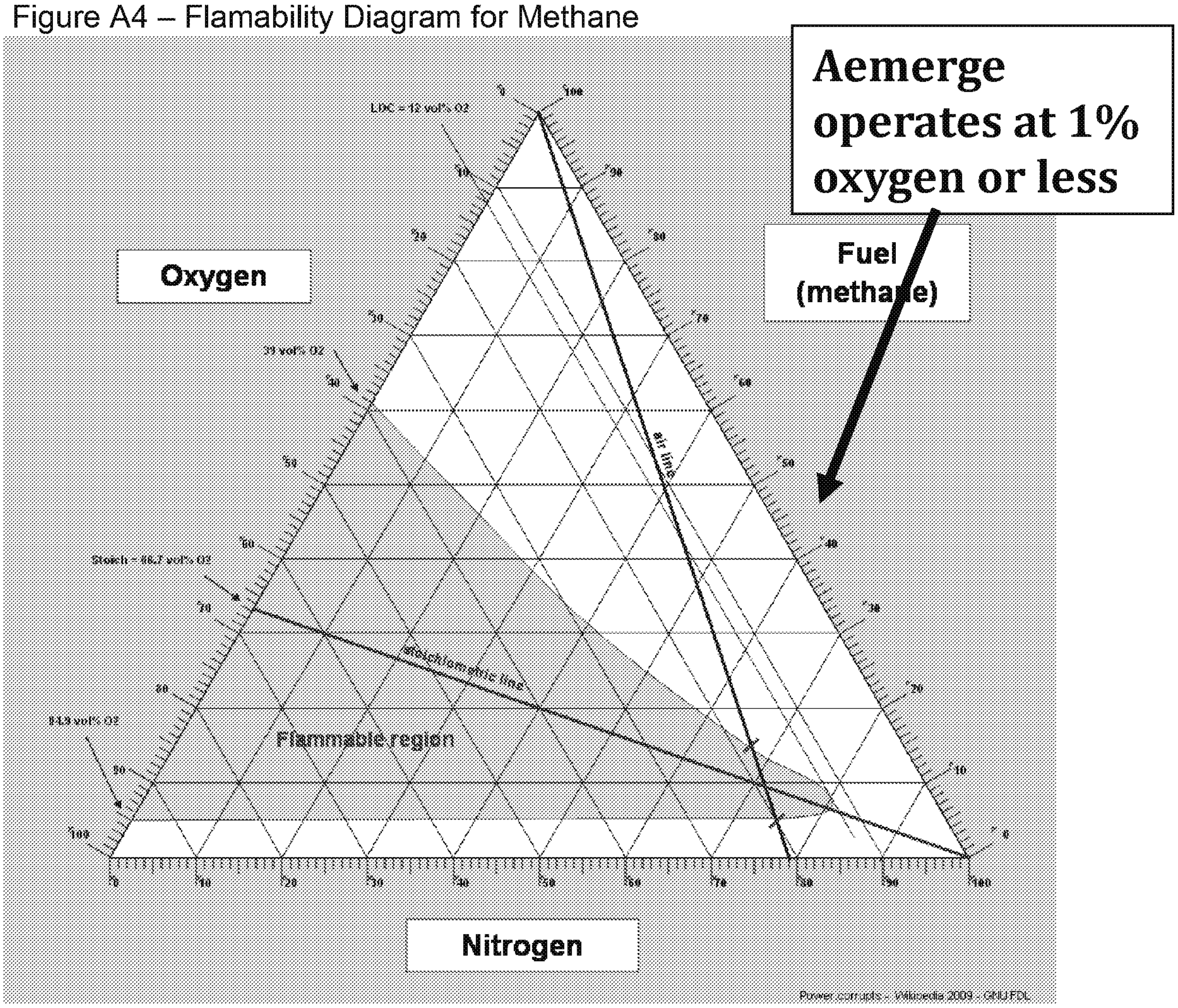
Technical Data - Protective gas: inert gas (e.g. nitrogen)

[HYPERLINK "https://www.ruhstrat.com/en/industrial-furnaces/industrial_furnace_constructio/carbon-fiber-and-graphite/carbonization-furnace.htm"]

The Aemerge unit is designed to process 5,800 pounds per hour of medical waste; this unit has 22.5 MMBtu of natural gas burners. At steady state operation, the unit is expected to operate at about 60% of the natural gas burner capacity. This results in a required heat input of 2,328 Btu per pound of waste processed. The Aemerge unit is endothermic and requires energy input of approximately 2,328 Btu per pound of waste. The Aemerge process is a continuous process, so it is always endothermic. The Aemerge process produces carbon that can be used as pigment for black coloration and char that can be charged with nutrient for landscape application. The product from the Aemerge unit in Indiana that processes wood pallets is sold as biochar under the trade name of Soil Charge©. The syngas gas produced by the carbonizer/gasifier will be beneficially reused for power generation. The current plan is for a heat recovery steam generator (HRSG) for heat recovery after the oxidizer. Aemerge also intends to look at syngas cleaning for use of the syngas in internal combustion electrical generation.

Figure 4 below show the flammability diagram for methane. Methane is the largest component of the Aemerge syngas and is also a readily combustible gas. Aemerge operates the carbonizer at one percent oxygen or less. Figure A4 shows that methane in air hits loss of combustion (LOC) at 12% oxygen. This figure illustrates that the Aemerge carbonizer operates well outside the limits of combustion and is not capable of sustaining combustion.

Figure A4 – Flamability Diagram for Methane



[HYPERLINK "https://en.wikipedia.org/wiki/Flammability_diagram"]

Other Regulatory Applicability Considerations

Aemerge asserts that the requirements of the Subpart Ec do not apply to the Aemerge process because the Carbonizer/Gasifier system is a pyrolysis unit. The Amerge process conforms to the above definition (40 CFR 60.51c) of pyrolysis. Significantly, the process is always endothermic, the process results in the gasification of medical waste and the process requires external energy from indirect heat supplied by natural gas burners or electric heaters that are completely sealed from the inner jacket (muffle) that contains the waste material.

Amerge further asserts that the Aemerge carbonizer process is not a combustion unit or incineration unit because the Aemerge unit cannot support combustion. Furthermore, EPA has stated that gasification is a chemical process and is not a combustion process. Because the Aemerge unit is not a combustion unit and does not support combustion, the Aemerge process is not subject to regulation under the authority of Section 129 of the CAA which regulates solid waste combustion.

EPA has also issued guidance on combustion and incineration. This guidance generally discusses facts relating to incineration as sustained, exothermic combustion. EPA has issued two prior determinations on medical waste applicability under Section 129. One determination concluded that the unit was endothermic and was not subject to Section 129 contingent on some additional demonstration and clarification of the facts of the matter. The second determination was for a plasma unit that was determined to be endothermic for at least a portion of the batch cycle and that based on the merits of the submitted information the process would be subject to the requirements of Section 129.
EPA has also made several conclusions regarding gasification. There is the "Gasification Rule" and the MaxWest determination for gasification of sewage sludge. EPA has typically made determinations on a case by case basis and gasification should be considered in this manner. Typical gasification processes are either air blown or oxygen blown. In blown gasification, the air or oxygen carries the syngas from the gasifier and produces heat and carbon monoxide from oxidation of carbonaceous matter in the gasifier. For blown gasification, consideration of whether the process is endothermic or exothermic due to partial oxidation could be a consideration for an EPA evaluation. In general, these processes are endothermic and the design focuses on supplying high quality syngas for later beneficial use. The Aemerge process uses nitrogen and negative pressure to prevent oxidation and to extract the syngas from the carbonizer. The relevant language in the statements below is highlighted in blue for easier reading.

Relevant EPA Statements

Statement 1
A 1995 EPA Office of Solid Waste memorandum concludes that a unit that "operates outside of the limits of flammability" "is not an incinerator".

1. Can you clarify the meaning of "controlled flame combustion," as specified in the incineration definition? Does this imply that an engineered burner must be utilized to generate "controlled flame?". We presume that an engineered burner is necessary for "flame combustion" to be considered "controlled," but would like confirmation.

Answer: Combustion is an exothermic chemical reaction involving the rapid thermal oxidation of a substance. Controlled flame combustion refers to a steady-stare, or near steady-state, process wherein fuel and/or oxidizer feed rates are controlled. An engineered burner is not necessarily needed in order for a combustion process to be considered controlled. EPA does not specify the term "engineered burner" in the RO 14238 regulatory definition for incineration devices. EPA notes there is not always a clear
distinction whether a particular process meets the definition of an incinerator. Some processes need to be evaluated on a sire-specific basis. Again, the important consideration is that appropriate controls be applied to the unit.

4. If a premixed, gaseous waste is processed in a device which uses a preheated

chamber at which the system is operated outside the limits of flammability, would this imply that a controlled flame is nor employed. and therefore it is nor considered incineration? We presume this to be the case but would like confirmation.
Answer: Controlled flame combustion is the defining character of incineration. If the system discussed operates outside the limits of flammability, such that a flame is never formed, it is reasonable to conclude that it is not an incinerator.
Response to Questions from California Department of Toxic Substances Control Regarding Various Issues on the Combustion of Hazardous Waste, Elizabeth A. Cotsworth, Acting Director Office of Solid Waste to Julie Anderson, Director Waste Management Division, Region IX

Statement 2
A Commercial and Industrial Solid Waste Incineration Unit (CISWI) is defined as:
"any combustion unit at a commercial or industrial facility that is used to combust solid waste."
EPA's response to comments on the Commercial/Industrial Solid Waste Incineration Rule reiterate the position made in the NHSW Rule – essentially that gas is not a solid waste, except in the rare case that it becomes containerized.

Comment: Several existing solid waste incinerator regulations (e. g., 40 CFR Part 60 Subpart Eb) include units which burn gasified solid waste as affected facilities. On June 30th, 2009, a letter was sent from Kentucky Energy and Environment Secretary Len Peters to EPA Administrator Lisa Jackson suggesting that those regulations be changed to exclude gasifiers from those regulations. Stephen Page, Director of the Office of Air Quality Planning and Standards, sent a response dated July 22nd 2009 concurring in general with that proposed change. Additionally, EPA recently issued a proposed rule on Identification of Non-Hazardous Secondary Materials That Are Solid Waste which specifically identifies gasification as an "Example of Adequate Processing" that can process non-waste fuel from solid waste (40 CFR Part 241). While the proposed New Source Performance Standards and Emission Guidelines for Commercial and Industrial Solid Waste Incineration Units does not include gasification the Division would like to see an explicit exclusion, whether in the preamble or the rule itself, exempting gasifiers of solid waste as affected facilities. The Division believes that such an exclusion is keeping with EPA's intent, but also believes that an explicit exclusion is desirable for clarity and to eliminate any possible questions.

Response: In Natural Resources Defense Council v. EPA, the Court held that the term "solid waste incineration unit" in CAA section 129(g)(1) "unambiguously include[s] among theincineration units subject to its standards any facility that combusts any commercial or industrial solid waste material at all—subject to the four statutory exceptions identified [in CAA section 129(g)(1)]." 489 F.3d 1250, 1257–58 (D.C. Cir. 2007). Combustion units located and commercial or industrial facilities that combust solid waste as that term is defined in the Nonhazardous Solid Waste Definition Rulemaking may be subject to CISWI, unless the unit is expressly exempt pursuant to section 129(g)(1). EPA is establishing standards for units at commercial or industrial facilities that meet the definition of "incinerators", "energy recovery units", "waste burning kilns", or "small-remote incinerators" in this final rule, and sources should consult the rule or their permitting authority to determine whether their combustion unit will be subject to the final standards issued today. To the extent gasified solid waste is not a solid waste as defined in the Non-hazardous Solid Waste Definition Rulemaking, units burning such gas will not be solid waste incineration units.

Document Control Number: EPA-HQ-OAR-2003-0119-2120.1, Comment Excerpt Number: 1
[HYPERLINK "http://www3.epa.gov/airtoxics/129/ciwi/ciswi_rtc_022011_master.pdf"]

Statement 3

The preamble of the CISWI clarifiers that gas (syngas) derived from solid waste is not solid waste unless containerized:

> Comment: Many commenters who supported the EPA retaining the 2000 CISWI rule's definition of "contained gaseous material" also urged the Agency to make clear that this definition should apply when interpreting the term "solid waste" under RCRA.
> Response: As aforementioned, the Agency is including the definition of "contained gaseous material" found in the 2000 CISWI Rule in today's final rule. Specifically, the definition of "contained gaseous material" is codified today, consistent with the 2000 CISWI Rule, as meaning, "gases that are in a container when that container is combusted."[4] CAA section 129(g)(6) states that the definition of "solid waste" shall have the meaning established by the Administrator pursuant to RCRA. We agree that the definition of contained gaseous materials in the final CISWI rule is consistent with the interpretation of that term under RCRA for the purpose of defining when non-hazardous secondary materials are solid wastes when combusted in CISWI units.[5] As discussed in more detail in the NHSM portion of the December 2011 reconsideration proposal and in various letters issued by EPA,[6] the NHSM rulemaking did not change any previous EPA position as it relates to whether "contained gaseous material" is a solid waste under RCRA."
> We note, however, that although gases must be "contained" to be solid wastes under RCRA, EPA maintains separate and independent authority under RCRA to regulate certain types of uncontained gases whether or not they themselves are solid wastes (e.g., gases emitted from the management of hazardous waste).
> 4 See 65 FR at 75359 and 75373.
> 5 Note that for the purposes of CISWI, contained gaseous materials are limited to gases in a container when that container is combusted. This limitation is due to the fact that CAA section 129 is focused exclusively on combustion of non-hazardous solid wastes. On the other hand, RCRA is focused on more than just combustion of non-hazardous solid wastes (e.g., treatment, storage, and disposal of hazardous and non-hazardous wastes); thus, this limitation is inapplicable to RCRA. We also note that the term 'container' as used in this definition is broader than the term as used in the hazardous waste regulations (see 40 CFR 260.10, definition of container). Specifically, the term

here is not limited to a portable device, but also includes stationary containers. We believe that these interpretations under the CAA and RCRA are consistent.

6 For example, see June 25, 2012 letter from Assistant Administrator Mathy Stanislaus to Paul Noe. A copy of this letter has been placed in the docket for today's rulemaking.
[HYPERLINK "http://www3.epa.gov/ttn/caaa/t1/fr_notices/ciswi_egfp.pdf"]

Statement 4

Section 129 of the CAA states"

c. Standards under section 111 and this section applicable to solid waste incineration units with capacity equal to or less than 250 tons per day combusting municipal waste and units combusting hospital waste, medical waste and infectious waste shall be promulgated not later than 24 months after the date of enactment of the Clean Air Act Amendments of 1990.

CAA: Section 129 of the Clean Air Act (CAA §129) required the EPA to develop and adopt performance standards for solid waste incineration units, including emission limitations, and defined the term, *solid waste incineration unit*:

"a distinct operating unit of any facility which combusts any solid waste material from commercial or industrial establishments or the general public".

The EPA recognizes seven types of flame combustion systems, or incinerators, regulated under CAA §129, and two additional types of combustors that fall under provisions of the Resource Conservation Recovery Act (RCRA) and the Toxics Substances Control Act (TSCA).10 These include: 1) large municipal waste combustors; 2) small municipal waste combustors; 3) hospital/medical/infectious waste incinerators; 4) commercial and industrial solid waste incineration units; 5) other solid waste incinerators; 6) sewage sludge incinerators; 7) hazardous waste incinerators and manufacturing waste incinerators; 8) boilers and industrial furnaces that burn solid waste; and 9) industrial, commercial, and institutional boilers that do not burn solid waste.

[HYPERLINK "http://www3.epa.gov/airtoxics/129/sec129.pdf"]

Statement 5

EPA's information on the Gasification Rule states EPA's position that gasification is a chemical process and is not combustion. As gasification is not combustion, gasification units cannot be combustion units regulated under Section 129 of the Clean Air Act.

Gasification Rule - EPA 2008

"Gasification is a chemical process that converts carbon-containing material into a synthesis gas that can be used for energy production or as a building block for other chemical manufacturing process. Gasifiers operate at high temperatures and pressure in a oxygen limited environment. Gasification is a chemical process, not a combustion process. The synthesis gas product from the gasifier is comprised primarily of carbon monoxide and hydrogen and is similar to natural gas. Gasification also can produce a concentrated carbon dioxide stream that may have a significant role in carbon sequestration in the future."

[HYPERLINK "http://www3.epa.gov/epawaste/hazard/wastetypes/wasteid/gas.htm" \l "faqs"]

Statement 6

In the EPA's MaxWest Determination Letter (December 19, 2013), EPA combines both of these factors to determine that gasification of sludge is not regulated under Section 129 for the MaxWest gasification process. Neither the gasification, nor the oxidization of the syngas is regulated for this facility.

The preamble to March 21, 2011, final rule describes an SSI unit as "an enclosed device or devices using controlled flame combustion that burns sewage sludge for the purpose of reducing the volume of sewage sludge by removing combustible matter." See 76 FR 15372. According to the information provided by MaxWest, no flame is applied or propogated in the gasifier and the gasifier prevents combustion by limiting the air-to-sludge ratio such that combustion cannot occur. Therefore, we do not believe that the gasifier is an SSI, because it does not combust sewage sludge.

With regard to the thermal oxidizer process heater, combustion of the syngas does take place in this unit. The definition of sewage sludge at Section 60.3930 includes "material derived from sewage sludge." According to the information provided by Maxwest, the syngas is derived from sewage sludge through the gasification process. The definition of sewage sludge is expressly limited to the "solid, semisolid, or liquid residue generated during the treatment of domestic sludge in a treatment works." Since syngas is a gas, and not a solid, semisolid, or liquid, it does not meet the definition of sewage sludge in the SSI EG rule (even though it is derived from sewage sludge). Therefore, EPA believes that the combustion of the syngas in MaxWest's thermal oxidizer process heater is not subject to the SSI EG Rule.

[HYPERLINK "http://www.houstontx.gov/onebinforall/Gasifier_Not_An_Incinerator.pdf"]

Statement 7

In an applicability determination regarding the definition of "pyrolysis unit" for the medical waste exemption under "the HMIWI regulations", EPA again uses the overall net energy input as the criteria. Low oxygen in the airlocked chamber apparently prevents combustion and EPA expects that gasification is occurring endothermically. EPA requests more information and expects that some demonstration of maintenance of these operating conditions would be part of operating this unit under the pyrolysis exemption.

"Because the natural gas (or pyrolysis gas) is pre-combusted in a substoichiometric mixture before entering the PTPSTM chamber, Statewide Medical Services claims that no oxygen is available to react with the waste material at the base of this chamber. They assert that any oxygen entering with the waste at the top of the PTPSTM chamber either: (1) is forced into the oxidation chamber before the waste material is hot enough to react with the oxygen, or (2) reacts with the hot natural gas rather than the relatively cool waste.

Under these conditions, the USEPA reasons that there may be an insignificant amount of oxygen in the PTPSTM chamber. By theoretically preventing the

reaction of the waste material with the oxygen, the waste material would be gasified endothermically. The energy used to gasify the waste material comes from the hot pre-combusted oxygen-free natural gas (an “external source” of energy).”
[HYPERLINK "http://yosemite.epa.gov/r5/r5ard.nsf/2134f82000aa062c86257577004df4d7/7ea207b44e70abab862574c8006e223c!OpenDocument"]

The Aemerge Technology

In the discussion above, the criteria that EPA has used to evaluate specific technologies has been discussed. This section looks at the Aemerge technology in detail in order to document the concepts developed in the previous sections. Highlighted information below confirms that the system is an inert gas (nitrogen) carbonizer system that pyrolyzes waste into carbon and syngas.

From US Patent #8,801,904:

CHAIN DRAG CARBONIZER, SYSTEM AND METHOD FOR THE USE THEREOF

Abstract

A drag chain carbonizer is provided with a system and methods for anaerobic thermal transformation processing to convert waste into various solid carbonized products and varied further co-products. The drag-chain carbonizer includes an adjustable bed depth mechanism, a heating mechanism, a pressure management mechanism, and a chain tensioning mechanism containing at least one position sensor for communication of an actuator position to at least one programmable logic controller (PLC). Carbonaceous waste is transformed into useful co-products that can be re-introduced into the stream of commerce at various economically advantageous points. Depending upon the input materials and the parameters selected to process the waste, including real time economic and other market parameters, the system adjusts co-products output to reflect changing market conditions.

Inventors: **Miller; Landon C.G.**; *(Indianapolis, IN)* ; **Behrens; Scott**; *(Indianapolis, IN)* ; **Rayles; Brian**; *(Indianapolis, IN)*

Applicant:	**Name**	**City**	**State**	**Country**	**Type**
	Aemerge, LLC	Indianapolis	IN	US	

Family ID: **49877676**
Appl. No.: **13/927904**
Filed: **June 26, 2013**

RELATED APPLICATIONS

[0001] This application claims priority benefit of U.S. Provisional Application Ser. No. 61/667,751, filed Jul. 3, 2012; and U.S. Provisional Application Ser. No. 61/793,078, filed Mar. 15, 2013; the contents of which are hereby incorporated by reference.

FIELD OF THE INVENTION

[0002] The present invention in general relates to a system for transforming organic waste into useful co-products, including hydrocarbon based gases, hydrocarbon-based liquids, and carbonized material; and in particular to a system having as its transformative element an anaerobic, negative pressure, or carbonization system.

BACKGROUND OF THE INVENTION

[0003] Pyrolysis is a general term used to describe the thermochemical decomposition of organic material at elevated temperatures without the participation of oxygen. Pyrolysis differs from other high-temperature processes like combustion and hydrolysis in that it usually does not involve oxidative reactions and is often characterized by irreversible simultaneous change of chemical composition and physical phase.

[0004] Pyrolysis is a case of thermolysis, and is most commonly used for organic materials, and is one of the processes involved in charring. Charring is a chemical process of incomplete combustion of certain solids when subjected to high heat. The resulting residue matter is called char. By the action of heat, charring reductively removes hydrogen and oxygen from the solid, so that the remaining char is composed primarily of carbon in a zero oxidation state. Polymers such as thermoplastics and thermoset, as well as most solid organic compounds like wood and biological tissue, exhibit charring behavior when subjected to a pyrolysis process, which starts at 200-300.degree. C. (390-570.degree. F.) and goes above 1000.degree. C. or 1800.degree. F., and occurs for example, in fires where solid fuels are burning. In general, pyrolysis of organic substances produces gas and liquid products and leaves a solid residue richer in carbon content, commonly called char. Extreme pyrolysis, which leaves mostly carbon as the residue, is called carbonization.

[0005] The pyrolysis process is used heavily in the chemical industry, for example, to produce charcoal, activated carbon, methanol, and other chemicals from wood, to convert ethylene dichloride into vinyl chloride to make PVC, to produce coke from coal, to convert biomass into syngas and biochar, to turn waste into safely disposable substances, and for transforming medium-weight hydrocarbons from oil into lighter ones like gasoline. These specialized uses of pyrolysis are called by various names, such as dry distillation, destructive distillation, or cracking. Efficient industrial scale pyrolysis has proven to be difficult to perform and adjust reactor conditions to feedstock variations in order to achieve a desired degree of carbonization.

[0006] Cogeneration also referred to as combined heat and power (CHP) is the use of a heat engine or a power station to simultaneously generate both electricity and useful heat. All thermal power plants emit a certain amount of heat during electricity generation. The heat produced during electrical generation can be released into the natural environment through cooling towers, flue gas, or by other means. By contrast, CHP captures some or all of the by-product heat for heating purposes, or for steam production. The produced steam may be used for process heating, such as drying paper, evaporation, heat for chemical reactions or distillation. Steam at ordinary process heating conditions still has a considerable amount of enthalpy that could be also be used for power generation.

DESCRIPTION OF THE INVENTION

[0038] An inventive drag chain carbonizer is provided with an apparatus and process for anaerobic thermal transformation processing to convert waste into bio-gas; bio-oil; carbonized materials; non-organic ash, and varied further co-products. In the inventive technology presented herein, any carbonaceous waste is transformed into useful co-products that can be re-introduced into the stream of commerce at various economically advantageous points. The present invention has utility to support a variety of processes, including to make, without limitation, carbon, carbon-based inks and dyes, activated carbon, aerogels, bio-coke, and bio-char, as well as generate electricity, produce adjuncts for natural gas, and/or various aromatic oils, phenols, and other liquids, all depending upon the input materials and the parameters selected to process the waste, including real time economic and other market parameters which can result in the automatic re-configuration of the system to adjust its output co-products to reflect changing market conditions. It is of note that conventional products such as coke, or activated carbons, or petroleum derived carbon blacks, all typically derived from coal and/or petroleum, contains numerous hazardous materials such as mercury, selenium, sulphur, and radioactive elements.

[0039] As used herein, the terms "carbonized material", "carbonaceous product" and "carbonaceous material" are used interchangeably to define solid substances at standard temperature and pressure that are predominantly inorganic carbon by weight and illustratively include char, bio-coke, carbon, activated carbon, aerogels, fullerenes, and combinations thereof.

[0052] Referring now to the figures, embodiments of an inventive implementation of a drag chain carbonizer are described. FIG. 1 is a diagram of a drag chain carbonizer 100 utilizing a drag-chain reactor 118 with a conveyor in the form of a drag-chain 120 with variable internal bed depth control 128 employing anaerobic thermal transformation processing to convert waste into bio-gas, bio-oil, char and non-organic ash. The drag-chain reactor 118 is appreciated to be either a single or multiple deck form thereof. The use of negative pressure throughout the system 100 is maintained by using a "liquid ring pump" (LRP) 308, for four various stages of gas scrubbing, as shown in FIG. 2. Various types of scrubbers operative herein, alone or in combination, include: venturi movement, impingement scrubber (perforated orifice plate with flooded top surface), down draft scrubber with optional heat exchanger and secondary cooling, and liquid ring pump. It is appreciated that multi-stage post reactor components are employed directly attached, as a single or multi-staged scrubbing system (see FIG. 2). Such scrubbing systems employ either water, or an organic solvent such as methanol, ethanol, or kerosene to inhibit tar and other high molecular weight aliphatic or aromatic formation. In certain inventive embodiments, the gas and oil separation-scrubbing system employs either a spray of water or a room temperature liquid organic solvent. Alternatively or in combination with quad scrub system 300, a distillation unit (not shown) is provided in certain in still other inventive embodiments for separating various molecular weight organics, or a batch hydrolysis process for producing tar or other high molecular weight products as exemplified by asphalt precursor oil.

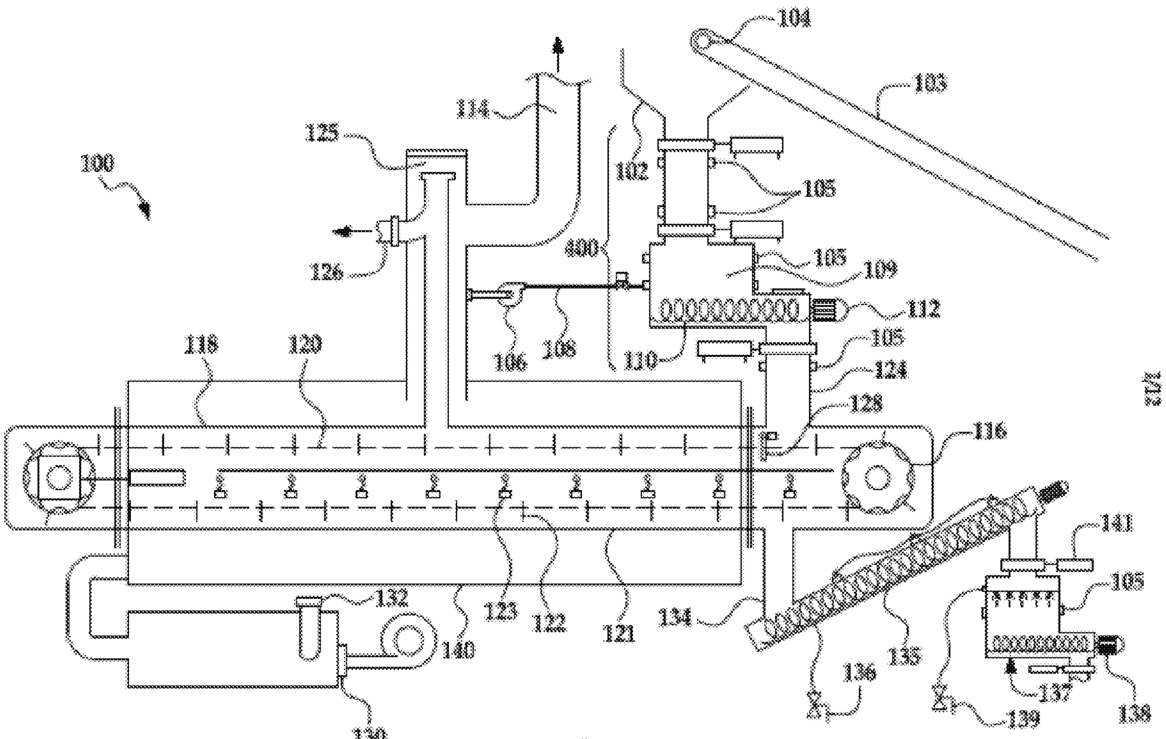


FIG. 1

[0053] A negative pressure/vacuum is also maintained in the system 100 through the use of a tri-lock feeder and pressure equalizer system 400 (see FIGS. 1 and 7) that is operative for purging, capturing, and pressure maintenance during metering incoming waste streams while maintaining negative pressure throughout the system 100, and by employing a sealed output shaft housing 372 that fastens directly to a sealed gearbox 374 as shown in FIG. 6 with shaft 352 linking a gear drive gearbox 374 to provide rotational movement of the drive chain sprockets 116 that move the conveyor in the form of a drag-chain 120 in the single or multiple deck reactor 118.

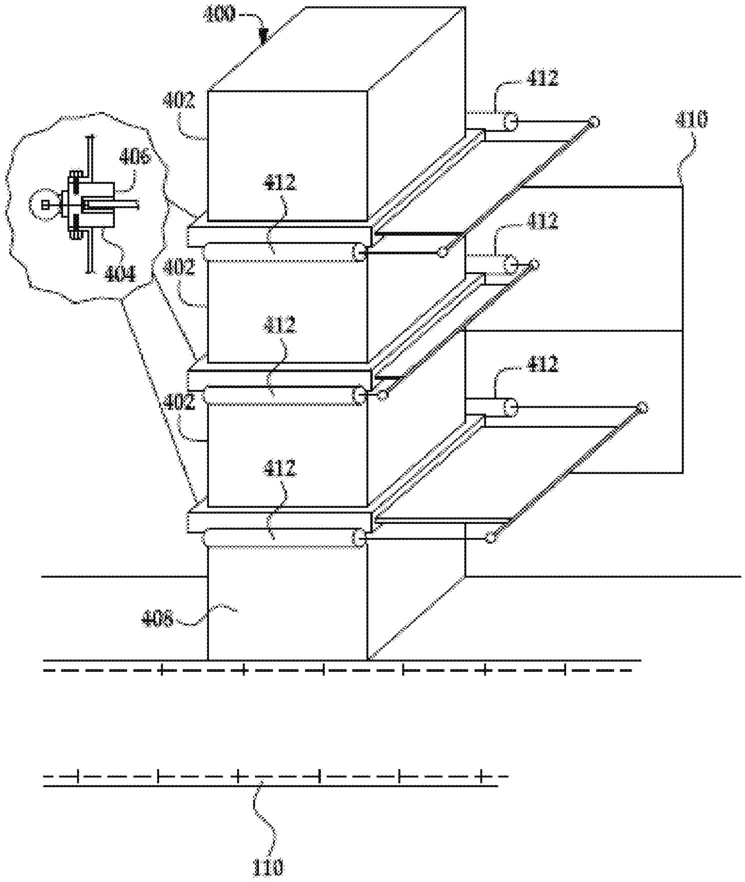


FIG. 7

[0057] In operation, feed material is transferred via a conveyor 103 driven by motor 104 and dispensed into a feed hopper 102 where it is dropped through the triple valve/tipping gate feed metering auger air lock system 400 regulated with the use of at least one sensor 105 to confirm and control material level (see FIGS. 1 and 7) where nitrogen or other inert gas can be injected via pipe 108 into the metering hopper 109 aiding to pre-heat the material and purge oxygen therefrom. It is appreciated that an upper feed lock system is configured differently than that shown at 400 to achieve atmospheric isolation and operates in certain inventive embodiments with less of the depicted complement of valves, sensors, and blowers to achieve an oxygen depleted environment. Following travel through the upper feed lock system 400, material dropped into the metering hopper 109 is transferred via auger 110, that is driven by motor 112 into the feed chute 124. The material drops down the chute 124 past the final airlock mechanism of system 400 and on to the conveyor drag-chain 120 in the reactor oven 118, where the material is heated while moving along the conveyor drag-chain 120.

The Design for Medical Waste in California

The design for California is detailed below in Figures A5 through A7. Figure A5 shows the major components of the system. Figure A6 shows the inert gas system which uses nitrogen to blanket the waste material as it travels down the muffle by way of the drag chain. The waste material is gasified and then carbonized in the process. Nitrogen is added and carried out under negative pressure to the oxidizer.

Figure A5 – The Aemerge System for Hesperia, California

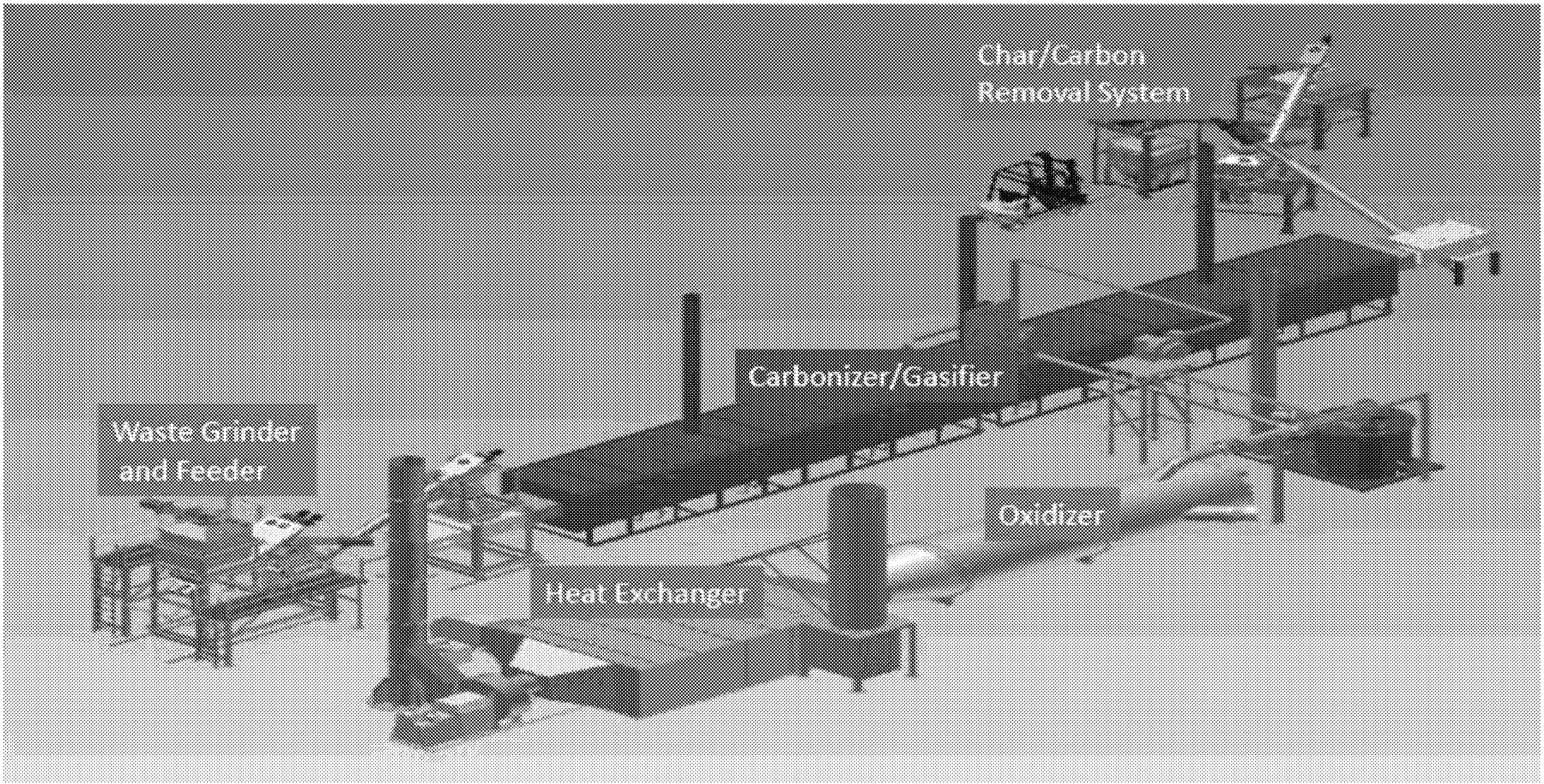


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Figure A6 – The Aemerge Inert Gas Carbonizer Furnace System with Gas Locks to Maintain Nitrogen Blanket and Negative Pressure

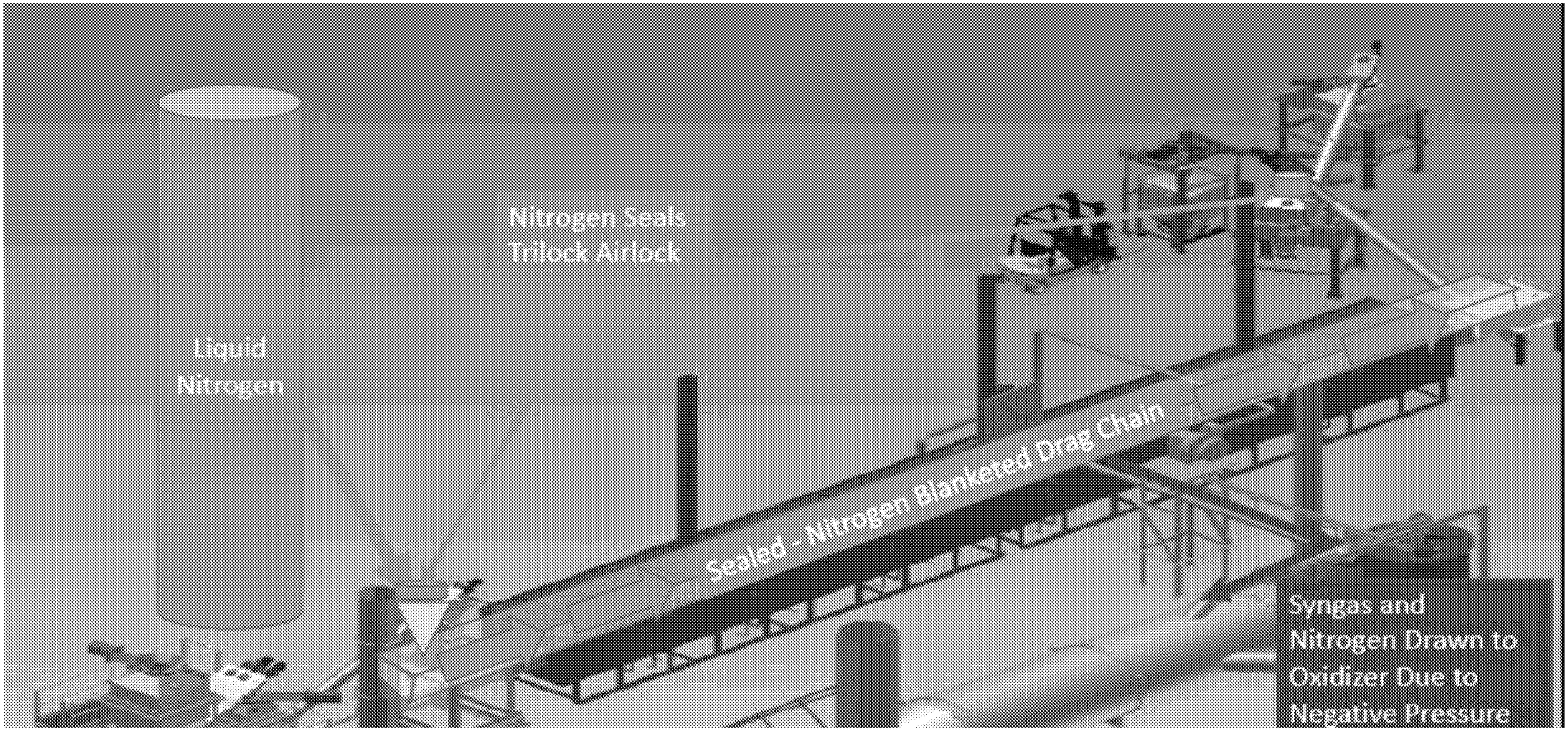

Figure A7 – The Aemerge Muffle Furnace Supplies Indirect Heat for Pyrolysis of Material Contained in the Nitrogen Blanketed Muffle

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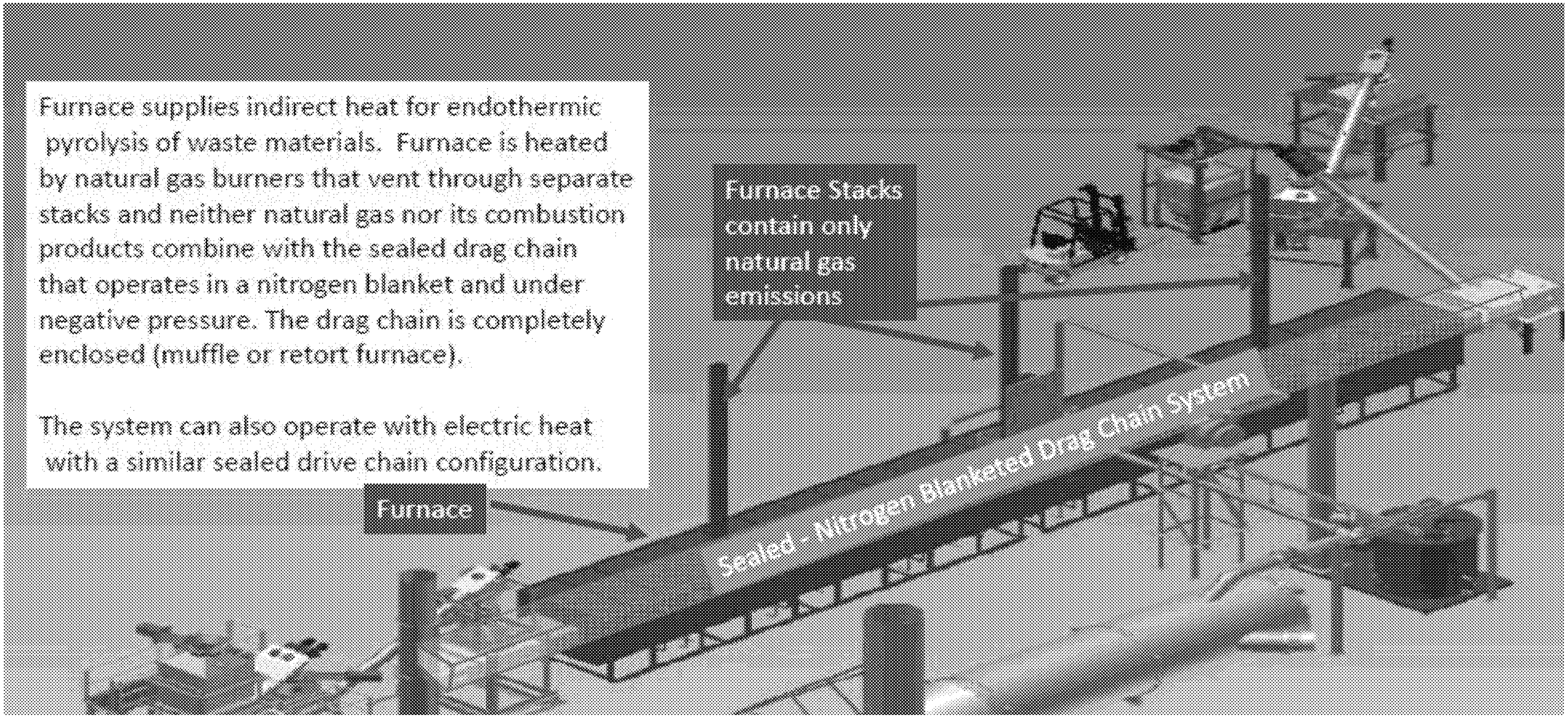
Furnace supplies indirect heat for endothermic pyrolysis of waste materials. Furnace is heated by natural gas burners that vent through separate stacks and neither natural gas nor its combustion products combine with the sealed drag chain that operates in a nitrogen blanket and under negative pressure. The drag chain is completely enclosed (muffle or retort furnace).
The system can also operate with electric heat with a similar sealed drive chain configuration.
Furnace Stacks contain only natural gas emissions
Furnace
Sealed - Nitrogen Blanketed Drag Chain System

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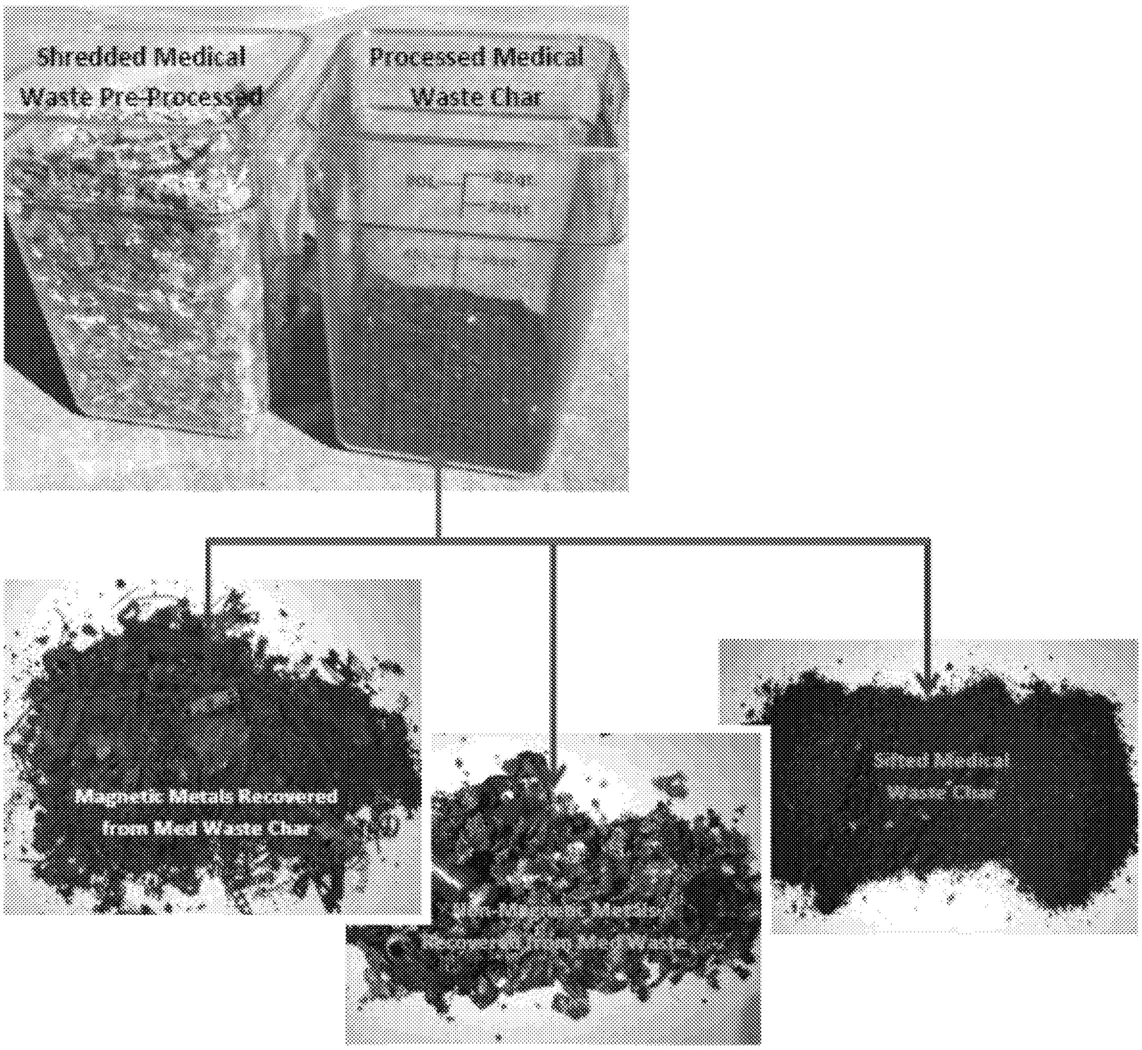
The Aemerge process results in the production of char or carbon that can be beneficially reused. High quality surgical metal is also recovered for recycling after passing through the Aemerge process. Other products such as glass are expected to be recyclable. Aemerge sees the same potential products to be derived from medical waste processing as from biomaterial processing including carbon, carbon-based inks and dyes, activated carbon, aerogels, bio-coke, and bio-char. Because of the inclusion of plastics in medical waste as well as a large amount of cellulose based (paper) products, the "bio" prefixes for product names will need to be reconsidered. Also, some applications like garden and food production with bio-char may not be realized due to a stigma attached to the origin of the char. As biochar is a high value commodity, a product for non-food use in agriculture is still expected.

Figure A8 – The Aemerge Carbonization Result



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Conclusions

The Aemerge technology meets the criteria for establishing pyrolysis and avoids the definitions of combustion, combustion unit, and incineration unit. According to EPA's criteria established by prior review and policy statements, EPA has determined that units that operate on low amount of air, such as blown air gasiifers, can avoid designation if they remain endothermic and operate outside of the limits of self-sustaining combustion (essentially another verification of remaining substantially endothermic) due to oxygen deprivation.

By these criteria, the Aemerge process exceeds the evaluation criteria of prior units. The Aemerge units operates at the lowest oxygen levels obtainable by using gas locks, negative pressure and oxygen deprivation. Also as discussed, this is done to optimize carbonization and is typical of a class of carbonization furnaces called inert gas carbonization furnaces.

The processes of extreme pyrolysis, which exceed gasification and lead to carbonization, are known chemical production processes. The Aemerge unit shares many design elements with these commercially available carbonizers. The Aemerge and Ruhstrat inert carbonization furnaces share inert, nitrogen gas, gas seals on the inlet and outlet, a sealed muffle filled with inert gas designed to exclude air and oxidization of the carbon, indirect heating and an muffle that can expand separately from the surrounding furnace. The Aemerge process is thus not an incineration process, but is a chemical process for the production of syngas by the pyrolysis process of gasification, and for the production of carbon by the pyrolysis process of carbonization.

Aemerge requests that EPA provide a determination that the requirements of 40 CFR 60 Subpart Ec are not applicable to the Aemerge process due to the pyrolysis exemption contained in this rule. Furthermore, Aemerge is requesting that EPA provide a determination that the Aemerge process is neither incineration nor combustion, under applicable EPA definitions and prior policy, and that the Aemerge unit is not an incineration unit or a combustion unit under Section 129 of the Clean Air Act of 1990.

For further information, please contact:
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Sincerely,

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